5 ASSESSMENT OF BIOLOGICAL CONDITION

This section presents the assessment results of the 3-year sampling effort, describing the biological condition of streams in the basins sampled by the Maryland Biological Stream Survey (MBSS, or the Survey). Identification of degraded and undegraded streams is based on the assignment of ratings for the fish Index of Biotic Integrity (IBI) and the benthic IBI. Streams are also evaluated using the Hilsenhoff Biotic Index for benthic macroinvertebrates. Finally, the section compares the results of the fish IBI with the benthic IBI and the Hilsenhoff Biotic Index.

5.1 INTRODUCTION TO THE INDEX OF BIOTIC INTEGRITY

The Index of Biotic Integrity is a stream assessment tool that evaluates biological integrity based on characteristics of the fish and benthic assemblage at a site. Biological integrity is defined as the ability to support and maintain a balanced, integrated, adaptive community of organisms having a species composition, diversity, and functional organization comparable to that of the natural habitat of the region (Karr and Dudley 1981 as cited in Karr 1991).

To develop an IBI, reference sites are selected to represent regional natural habitats, also referred to as "minimally impacted" conditions. We recognize that virtually no streams in Maryland are entirely undisturbed by human activities. Atmospheric deposition of contaminants alone reaches all parts of the State, few streams have natural temperature regimes, and more than 1,000 man-made barriers to fish migration have been documented in Maryland. Therefore, our reference conditions should not be viewed as completely natural or pristine. They are, however, a representative sample of the best streams that currently exist in the State. Whether these conditions are the best attainable depends on future restoration activities and the goals of DNR and the public.

By definition, reference conditions represent minimally impacted conditions or those approximating "natural habitats." While some have suggested that reference conditions can be developed for particular situations where human impact is evident, such as urban streams, we have not taken this approach. Instead, reference sites were used to establish appropriate expectations, based on minimally impacted sites within a geographic region, and urban streams are rated on the same scale as other sites in the region. Although some urban streams may not be able to recover to a level comparable to the best natural habitats, appropriate management goals could be set using some intermediate IBI value as a desirable goal. This strategy could be used to maintain or restore a heavily impacted stream to a level of biological condition that is practical and attainable, given its history of degradation and current level of watershed development.

5.2 INTERPRETING THE INDEX OF BIOTIC INTEGRITY

Sites were evaluated using both the fish and benthic IBIs developed for the MBSS (for detailed methods, see Roth et al. 1997 and Stribling et al. 1998). IBI scores for the MBSS are determined by comparing the fish or benthic assemblages at each site to those found at minimally impacted reference sites. Three separate formulations were employed for the fish IBI, one for each of three distinct geographic areas: Coastal Plain, Eastern Piedmont, and Highland (Figure 5-1). The two formulations used for the benthic IBI cover the Coastal Plain and non-Coastal Plain regions. Individual metrics for the IBI are scored 1, 3, or 5, based on comparison with the distribution of metric values at reference sites (see Tables 5-1 to 5-4). For either the individual metrics or total IBI, a score of 3 or greater is considered comparable to reference site conditions, while scores falling below this threshold differ significantly from the reference conditions, as shown in Figure 5-2. Scores for the MBSS IBIs are calculated as the mean of the individual metric scores and therefore range from 1 to 5. Some other programs have used a similar approach (e.g., Weisberg et al. 1997), while others have instead computed the IBI as the total of individual metric scores. For example, Karr et al. (1986) calculated IBI as the sum of 12 metric scores, with totals ranging from 12 to 60 points.

Site-specific IBI results were used to estimate the extent of non-tidal streams in good, fair, poor, and very poor condition with respect to the biotic integrity of the fish or benthic community. Table 5-5 contains detailed descriptions for each of the IBI categories developed for the MBSS. The IBI score of 3 represents the threshold of reference condition and thus was used to designate sites known to be degraded (i.e., poor or very poor). The highest scores were designated as good recognizing that reference sites may not represent the highest attainable condition. The assignment of scores to narrative categories is a useful method for translating scores into a form that is easily

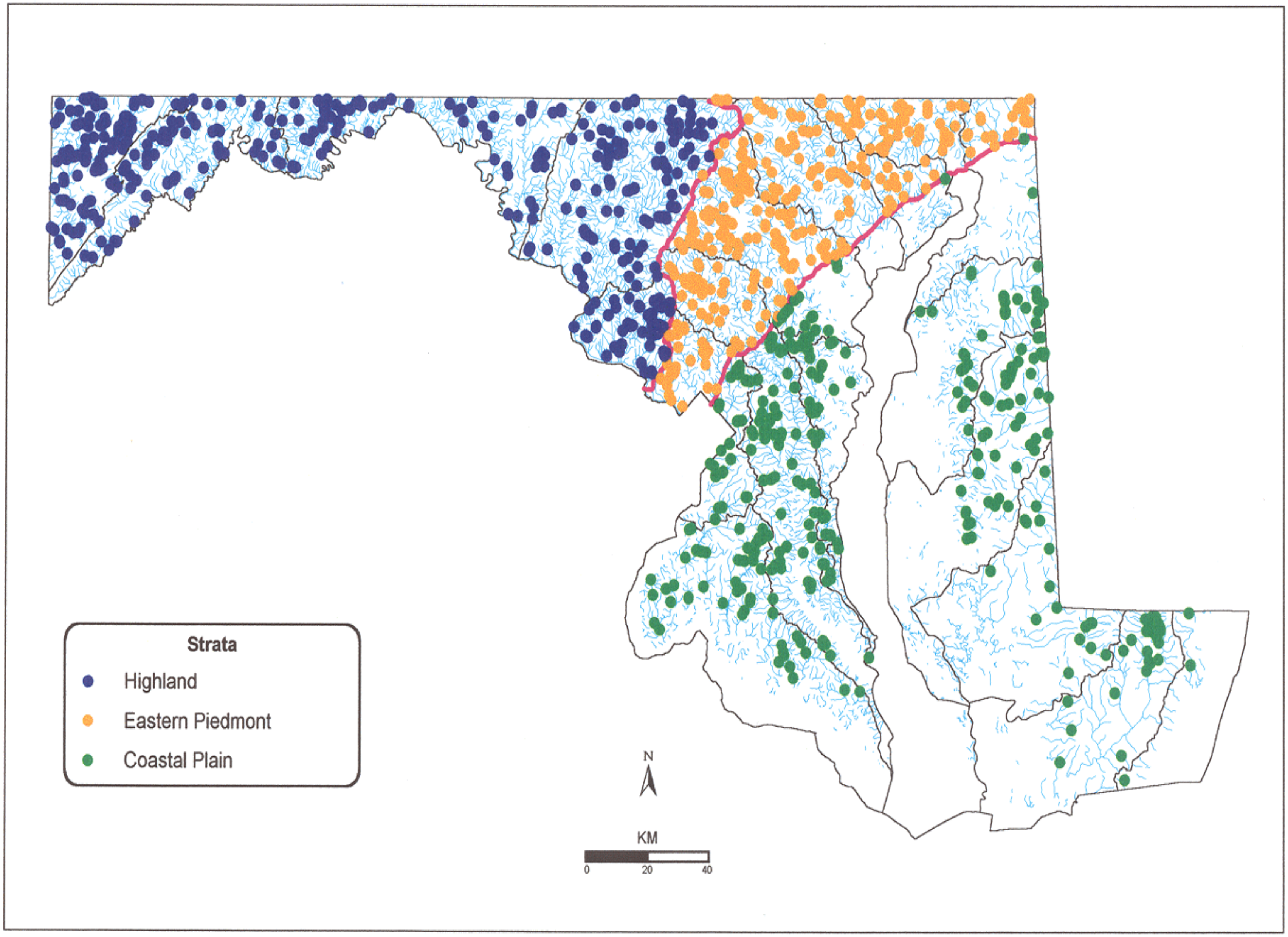

Figure 5-1. The three geographic regions used for the derivation of the fish Index of Biotic Integrity: Coastal, Piedmont, and Highland.

Table 5-1. Metrics and scoring criteria for the recommended final fish IBI. Some metrics[a] were adjusted for watershed area, based on linear relationships between the metric and log(watershed area)[b] in acres

	Scoring criteria		
	5	**3**	**1**
Coastal Plain			
Number of native species[a]	Criteria vary with stream size (see below)		
Number of benthic fish species[a]	Criteria vary with stream size (see below)		
Number of intolerant species[a]	Criteria vary with stream size (see below)		
Percent tolerant fish	≤ 50	$50 < x \leq 93$	> 93
Percent abundance of dominant species	≤ 33	$33 < x \leq 78$	> 78
Percent generalists, omnivores, and invertivores	≤ 92	$92 < x < 100$	100
Number of individuals per square meter	≥ 0.79	$0.42 \leq x < 0.79$	< 0.42
Biomass (g) per square meter	≥ 9.9	$3.6 \leq x < 9.9$	< 3.6
Eastern Piedmont			
Number of native species[a]	Criteria vary with stream size (see below)		
Number of benthic fish species[a]	Criteria vary with stream size (see below)		
Number of intolerant species[a]	Criteria vary with stream size (see below)		
Percent tolerant fish	≤ 41	$41 < x \leq 65$	> 65
Percent abundance of dominant species	≤ 30	$30 < x \leq 52$	> 52
Percent generalists, omnivores, and invertivores	≤ 86	$86 < x \leq 99.7$	> 99.7
Number of individuals per square meter	≥ 0.81	$0.35 \leq x < 0.81$	< 0.35
Biomass per square meter	≥ 8.0	$3.7 \leq x < 8.0$	< 3.7
Percent lithophilic spawners	≥ 62	$22 \leq x < 62$	< 22
Highland			
Number of benthic fish species[a]	Criteria vary with stream size (see below)		
Number of intolerant species[a]	Criteria vary with stream size (see below)		
Percent tolerant fish	≤ 28	$28 < x \leq 71$	> 71
Percent abundance of dominant species	≤ 49	$49 < x \leq 91$	> 91
Percent generalists, omnivores, and invertivores	≤ 49	$49 < x \leq 92$	> 92
Percent insectivores	≥ 48	$8 \leq x < 48$	< 8
Percent lithophilic spawners	≥ 70	$42 \leq x < 70$	< 42

Table 5-1. Cont'd

(a) Adjusted value = observed value/expected value, where expected value = m * log(watershed area in acres) + b.

	Scoring criteria		
	5	**3**	**1**
Coastal Plain			
Number of native species - Adjusted value	$\geq$ 1.06	0.53 $\leq$ x <1.06	< 0.53
Number of benthic fish species - Adjusted value	$\geq$ 1.06	0 < x < 1.06	0
Number of intolerant species Adjusted value	$\geq$ 0.34	0 < x < 0.34	0
Eastern Piedmont			
Number of native species - Adjusted value	$\geq$ 1.02	0.56 $\leq$ x < 1.02	< 0.56
Number of benthic fish species - Adjusted value	$\geq$ 0.99	0.50 $\leq$ x < 0.99	< 0.50
Number of intolerant species Adjusted value	$\geq$ 0.59	0.18 $\leq$ x < 0.59	< 0.18
Highland			
Number of benthic fish species - Adjusted value	$\geq$ 1.03	0.33 $\leq$ x < 1.03	< 0.33
Number of intolerant species Adjusted value	$\geq$ 0.73	0.23 $\leq$ x < 0.73	< 0.23

(b) Slope and intercept values for selected metrics, based on linear regression relationships between metric and log(watershed area) in acres

	slope (m)	**intercept(b)**
Coastal Plain		
Number of native species	6.5936	-13.0055
Number of benthic fish species	1.5743	-3.3929
Number of intolerant species	2.1485	-5.286
Eastern Piedmont		
Number of native species	5.5701	-8.1135
Number of benthic fish species	1.3245	-2.6437
Number of intolerant species	4.4052	-8.8991
Highland		
Number of benthic fish species	1.6067	-3.5202
Number of intolerant species	3.0723	-7.3029

Table 5-2. Description of fish IBI metrics

Number of native species (adjusted for watershed area) - Total number of native fish species; adjusted for watershed area (see Table 5-1b). Fishes were classified as native or introduced to Chesapeake Bay or Youghiogheny/Ohio River drainage.

Number of benthic fish species (adjusted for watershed area) - The number of fish species that reside primarily on the stream bottom, adjusted for watershed area (see Table 5-1b). Benthic fishes include all darters (*Etheostoma* spp., *Perca* spp.), sculpins (*Cottus* spp.), madtoms (*Noturus* spp.), and lampreys (*Petromyzon* spp., *Lampetra* spp.).

Number of intolerant species (adjusted for watershed area) - The number of fish species rated as intolerant of anthropogenic stress, adjusted for watershed area. Tolerance ratings (intolerant, tolerant) were based on statewide analysis comparing species occurrences with presence/absence of anthropogenic stressors.

Percentage tolerant fish - Percentage of individuals rated as tolerant to anthropogenic stress.

Percentage abundance of dominant species - Percentage of individuals within the single most abundant (dominant) species at a site.

Percentage generalists, omnivores, and invertivores - Percentage of individuals classified into the trophic groups of generalist, omnivore, or invertivore; these are the most general of all feeding habits. Invertivores eat insects and other invertebrates including crustaceans, mollusks, and worms. Omnivores consume two or more food types (insects, invertebrates other than insects, fish, plankton, algae, vascular plants, and detritus) with the exception of the combination of invertebrates and fishes. Generalists eat both invertebrates and fishes but not other food items.

Percentage insectivores - Percentage of individuals classified into the group insectivore; this is a specialized trophic group, feeding almost exclusively on insects.

Number of individuals per square meter - The number of individuals captured at a site, divided by the surface area fished. Surface area was computed as length of stream fished (usually 75 m) multiplied by average stream width.

Biomass (g) per square meter - Total mass in grams of fish captured at a site, divided by the surface area fished.

Percentage lithophilic spawners - Percentage of individuals reported to use rock substrates for spawning.

Table 5-3. Metrics and scoring criteria for the benthic IBI. From Stribling et al. 1998.

	Scoring Criteria		
	5	**3**	**1**
Coastal Plain			
Total taxa	>24	11<x<24	<11
EPT taxa	6	3<x<6	<3
% Ephemeroptera	>11.4	2.0<x< 11.4	<2.0
% Tanytarsini of Chiron.	>13.0	0.0<x<13.0	<0.0
Beck's Biotic Index	>12	4<x<12	<4
Scraper taxa	>4	1<x< 4	<1
% clingers	>62.1	38.7<x< 62.1	<38.7
Non-Coastal Plain			
Total taxa	>22	16<x<22	<16
EPT taxa	>12	5<x<12	<5
Ephemeroptera taxa	>4	2<x<4	<2
Diptera taxa	>9	6<x< 9	<6
% Ephemeroptera	>20.3	5.7<x<20.3	<5.7
% Tanytarsini	>4.8	0.0<x<4.8	<0.0
Intolerant taxa	>8	3<x<8	<3
% tolerant	<11.8	11.8<x< 48.0	>48.0
% collectors	>31.0	13.5<x<31.0	<13.5

Table 5-4. Description of benthic IBI metrics

Total number of taxa - Total number of benthic taxa in the sample. This measures the overall variety of the macroinvertebrate assemblage.

Number of EPT taxa - Number of taxa in the insect orders Ephemeroptera (mayflies), Plecoptera (stoneflies), and Trichoptera (caddisflies).

Number of Ephemeroptera taxa - Number of mayfly taxa.

Number of Diptera taxa - Number of “true” fly taxa, including midges.

Percentage Ephemeroptera - Percentage of mayfly individuals in the sample.

Percentage Tanytarsini of Chironomidae - Percentage of chironomids in the tribe Tanytarsini.

Percentage Tanytarsini - Percentage of Tantarsini midges to total fauna in the sample.

Number of intolerant taxa - Number of taxa considered to be sensitive to perturbation (Hilsenhoff values 0-3).

Percentage tolerant - Percentage of individuals in taxa considered tolerant of perturbation (tolerance values 7-10).

Beck’s Biotic Index - Weighted sum of intolerant taxa, equal to 2 x (number of Class 1 taxa + number of Class 2 taxa), where Class 1 taxa have tolerance values 0 and 1, and Class 2 taxa have tolerance values from 2 to 4.

Number of scraper taxa - Number of taxa that scrape food from substrate.

Percentage collectors - Percentage of individuals that feed on detrital deposits or loose surface films.

Percentage clingers - Percentage of individuals that are adapted for inhabiting flowing water, such as riffles.

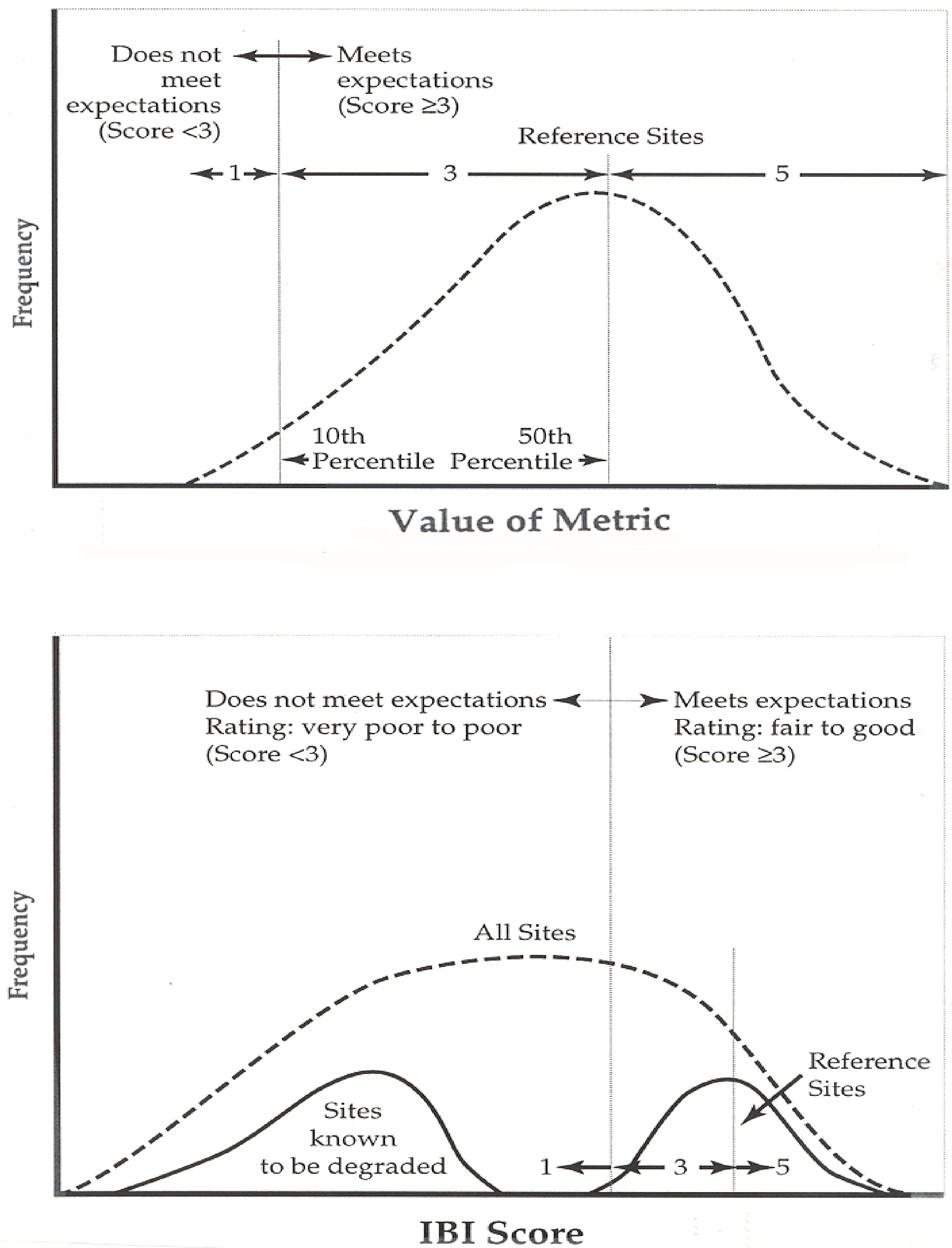

Figure 5-2. Derivation and interpretation of scores for the MBSS fish and benthic Indices of Biotic Integrity (IBI). Scores are based on the distribution of reference sites, as depicted in the top figure. The bottom figure shows reference sites in the context of other sites, including those with known degradation.

Table 5-5.	Narrative descriptions of stream biological integrity associated with each of the IBI categories	
Good	IBI score 4.0 - 5.0	Comparable to reference streams considered to be minimally impacted. Fall within the upper 50% of reference site conditions.
Fair	IBI score 3.0 - 3.9	Comparable to reference conditions, but some aspects of biological integrity may not resemble the qualities of these minimally impacted streams. Fall within the lower portion of the range of reference sites (10th to 50th percentile).
Poor	IBI score 2.0 - 2.9	Significant deviation from reference conditions, with many aspects of biological integrity not resembling the qualities of these minimally impacted streams, indicating some degradation.
Very Poor	IBI score 1.0 - 1.9	Strong deviation from reference conditions, with most aspects of biological integrity not resembling the qualities of these minimally impacted streams, indicating severe degradation.

communicated. Similar approaches have been used in other IBI applications (Karr 1991, Ohio EPA 1987, Ranasinghe et al. 1996).

5.2.1 Special Considerations in Interpreting IBI Scores

Several basins in Maryland contain streams that can be classified as coldwater stream systems. Lyons et al. (1996) and Leonard and Orth (1986) have pointed out the need to modify the IBI for use with coldwater streams, to account for their unique biological characteristics. Generally, high-quality coldwater streams are dominated by salmonid species like brook trout and have lower overall species richness than warmwater systems of the same area. In other parts of North America, fish IBI scores for coldwater and coolwater streams have been tailored to account for their unique biological characteristics. The three regional fish IBIs were used to assess all MBSS sites. However, because the IBI may underrate coldwater streams owing to their naturally low species diversity, the presence of brook trout was used as a secondary indicator in interpreting fish IBI scores. Sites where brook trout were present and fish IBI scores were less than 3 were excluded from analysis and reported as "not rated." This situation was rare (14 sites) compared to the total number of brook trout sites (70 sites).

Other types of natural variability should be considered in applying the IBI, especially in areas expected to differ in species richness and diversity. Naturally acidic blackwater streams may have lower species richness and be dominated by a few acid-tolerant species. A total of 24 MBSS sites were identified as blackwater streams, defined here as sites with either pH < 5 or ANC < 200 µeq/l and DOC $\geq$ 8 mg/l. Because of the concern for possibly underrating blackwater streams, the nine blackwater streams with fish IBI scores less than 3 were excluded from analysis and were therefore included in the category "not rated." Maryland DNR is considering developing separate IBIs for more stream types in the future.

Other factors that may affect fish IBI scores should be considered in interpreting scores for individual sites. Small streams with shallow stream channels may naturally support few species. Dams and other barriers to fish migration can block access to formerly inhabited upstream areas. In contrast, proximity of a site to a lake, pond, swamp, or impoundment in a watershed can make a site more accessible to lentic species not typically found in the small streams sampled by the Survey. Nearness to a large river confluence can similarly alter the pool of available species. Finally, high species richness owing to the presence of both Coastal Plain and Piedmont species at sites along the Fall Line may result in artificially high IBI scores in this transitional area.

5.3 BIOLOGICAL INDICATOR RESULTS

5.3.1 Fish IBI Results

Fish IBI scores for sites sampled in the 1995-1997 MBSS spanned the full range of biological conditions, from 5.0 for good streams to 1.0 for very poor streams. Site-specific data were used to estimate the percentage of stream miles in each of the four narrative categories. Estimates were calculated by basin, by stream order, and statewide.

Statewide, the highest percentage of stream miles were in fair condition (26% of stream miles in the study area), based on biological assessments using the fish IBI. An estimated 20% of stream miles were in good condition, 15% of stream miles were in poor condition, and 14% were very poor. A total of 74% of stream miles were rated. The remainder were primarily very small headwater streams (<300 acre watershed) where expectations of fish abundance and diversity are too low for development of an effective indicator. As would be expected, all the watersheds less than 300 acres occurred among first-order streams, most notably in western Maryland. In general, the sample frame included more streams with small watersheds in the western part of the state, where the density of streams is greater. An estimated 63% of first-order stream miles were assigned an IBI score, while 98% of both second- and third-order streams were rated.

Of the 17 basins sampled in the Survey, 14 had fish IBI scores spanning the full range of values from good to very poor. The basins that did not contain the full range of scores included the eastern Maryland basins: Gunpowder, Bush, Elk, Choptank (1996 sampling), Nanticoke/-Wicomico, and Pocomoke basins. These basins each had no sites that were rated as very poor. In addition, the Choptank (1996 sampling) also had no stream miles rated as poor, while the remaining five basins had only a small percentage of sites rated poor (less than 25%). The basin with the highest percentage of stream miles rated as good was the Elk (38%), while the basin with the highest percentage of stream miles rated as very poor was the North Branch Potomac (29%). Figures 5-3, 5-4, and 5-5 and Table 5-6 show a breakdown of fish IBI scores by basin and stream order. A statewide map shows the geographic distribution of IBI scores for each drainage basin (Figure 5-6).

First-order streams had a smaller percentage of stream miles in the good and fair categories, and a greater percentage rated very poor, than did larger streams. This most likely indicates more highly impacted conditions in first-order streams across these basins, or may also reflect a tendency for the IBI to underrate small streams, even though scoring already accounts for some effects of watershed size.

5.3.2 Benthic IBI Results

Benthic macroinvertebrate IBI scores for sites sampled in the 1995-1997 MBSS spanned the full range of biological conditions, from 5.0 for good streams to 1.0 for very poor streams. Site-specific data were used to estimate the percentage of stream miles in each of the four narrative categories. Estimates were calculated by basin, by stream order, statewide.

Statewide, the largest percentage of the stream miles were in fair condition (38% of stream miles) , based on biological assessments using the benthic IBI. An estimated 11% were in good condition, 26% were poor, and 25% were very poor. A total of 99.4% of streams were assigned benthic IBI scores. Because some metrics used to calculate the benthic IBI may not perform well when subsamples contain low numbers of individuals, the land use, water chemistry, physical habitat, and sample processing data from MBSS sites with less than 60 individuals were examined to determine if low numbers were likely a result of sampling error or stream quality. A benthic IBI score was calculated for sites of obviously poor quality. The small percentage of sites for which low numbers of individuals could be attributed to sampling error were not assigned a benthic IBI and were therefore included in the "not rated" category.

Of the 17 basins sampled in the Survey, 13 had benthic IBI scores that spanned the full range of values from good to very poor. The basins that did not contain the full range of scores were the Middle Potomac, Bush, Susquehanna, Elk, and Choptank (1997 sampling) basins. Of these, the Middle Potomac, Bush, Elk and Choptank (1997 sampling) basins each had no sites with IBI scores rated as good, while the Susquehanna had no sites that rated as very poor. In addition, the Pocomoke basin showed only 0.3% of stream miles rated as good. The basin with the greatest percentage of stream miles rated good was the 1995 sampling of the Youghiogheny (44%). The West Chesapeake (70%) and Pocomoke (69%) basins show the greatest percentage of stream miles that rated very poor. Figures 5-7, 5-8, and 5-9 and Table 5-7 show a breakdown of benthic IBI scores by basin and stream order. A statewide map (Figure 5-10) shows the geographic distribution of site IBI scores throughout the sample area.

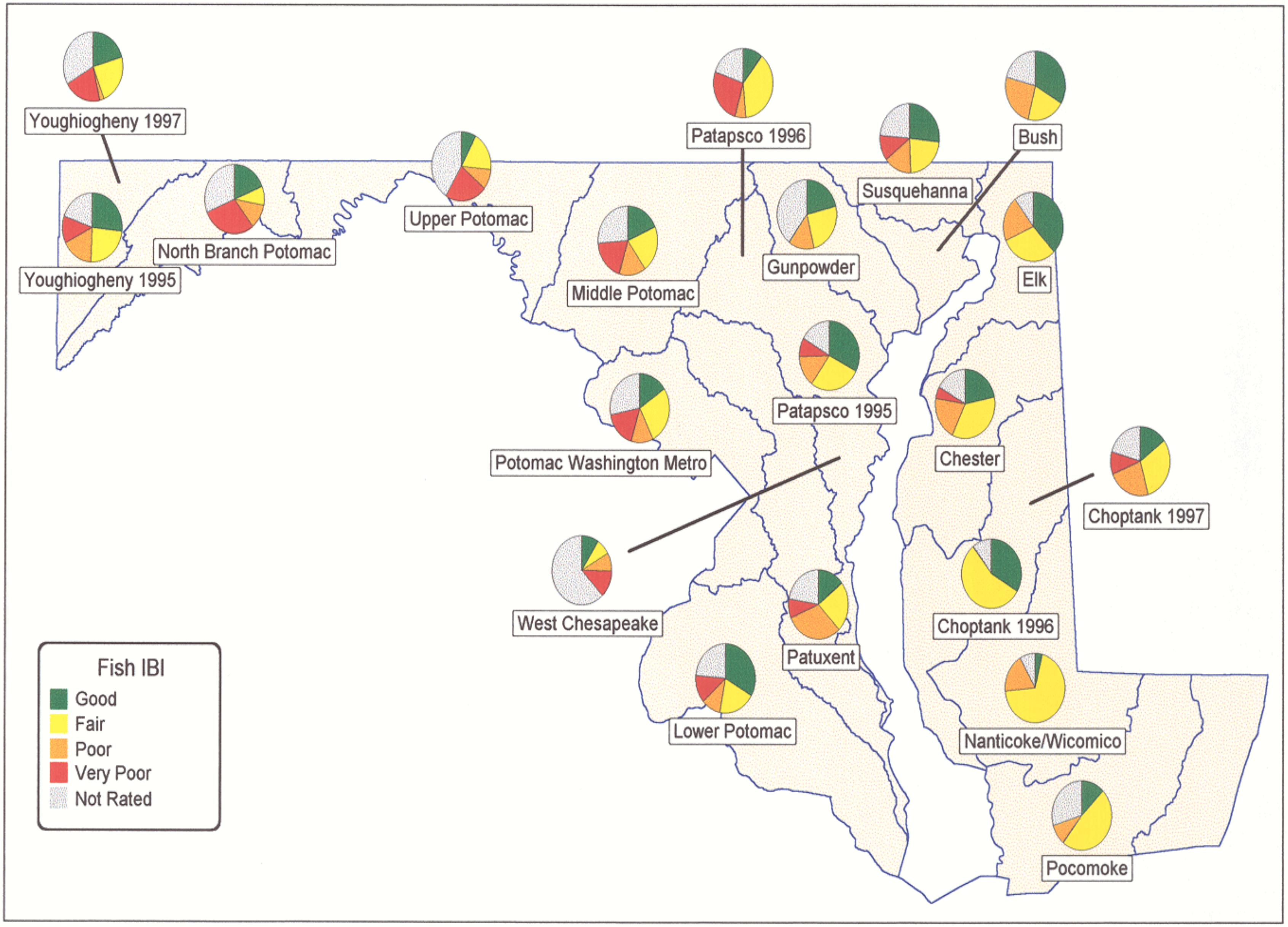

Figure 5-3. Geographic distribution of fish Index of Biotic Integrity scores for basins sampled in the 1995-97 MBSS, as the percentage of stream miles in each category: 4.0 - 5.0 good, 3.0 - 3.9 fair, 2.0 - 2.9 poor, and 1.0 - 1.9 very poor. No IBI score was assigned to sites with watershed area < 300 acres.

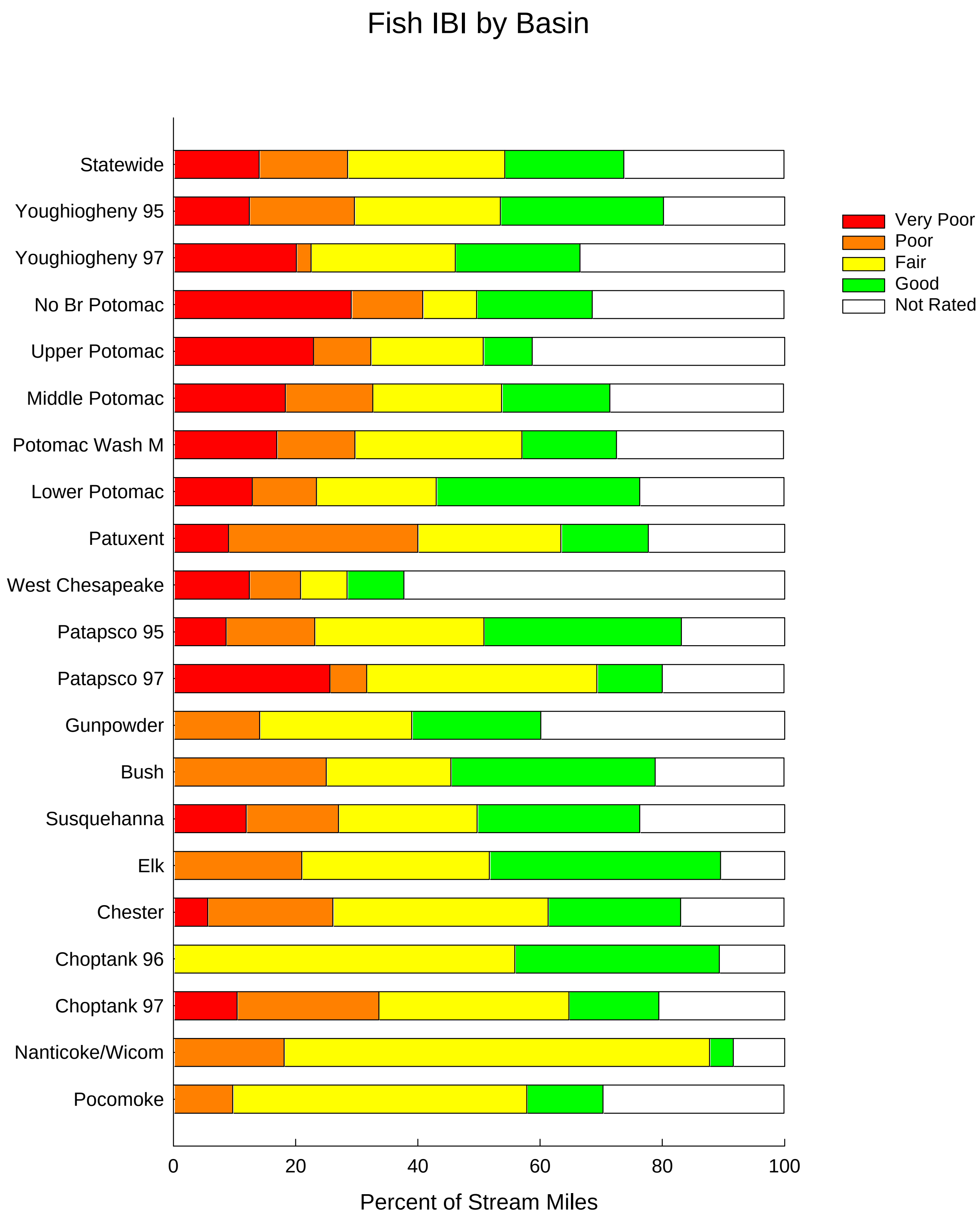

Figure 5-4. Fish Index of Biotic Integrity (IBI) scores for basins sampled in the 1995-97 MBSS, as the percentage of stream miles in each category: 4.0 - 5.0 good, 3.0 - 3.9 fair, 2.0 - 2.9 poor, and 1.0 - 1.9 very poor. No IBI score was assigned to sites with watershed area < 300 acres.

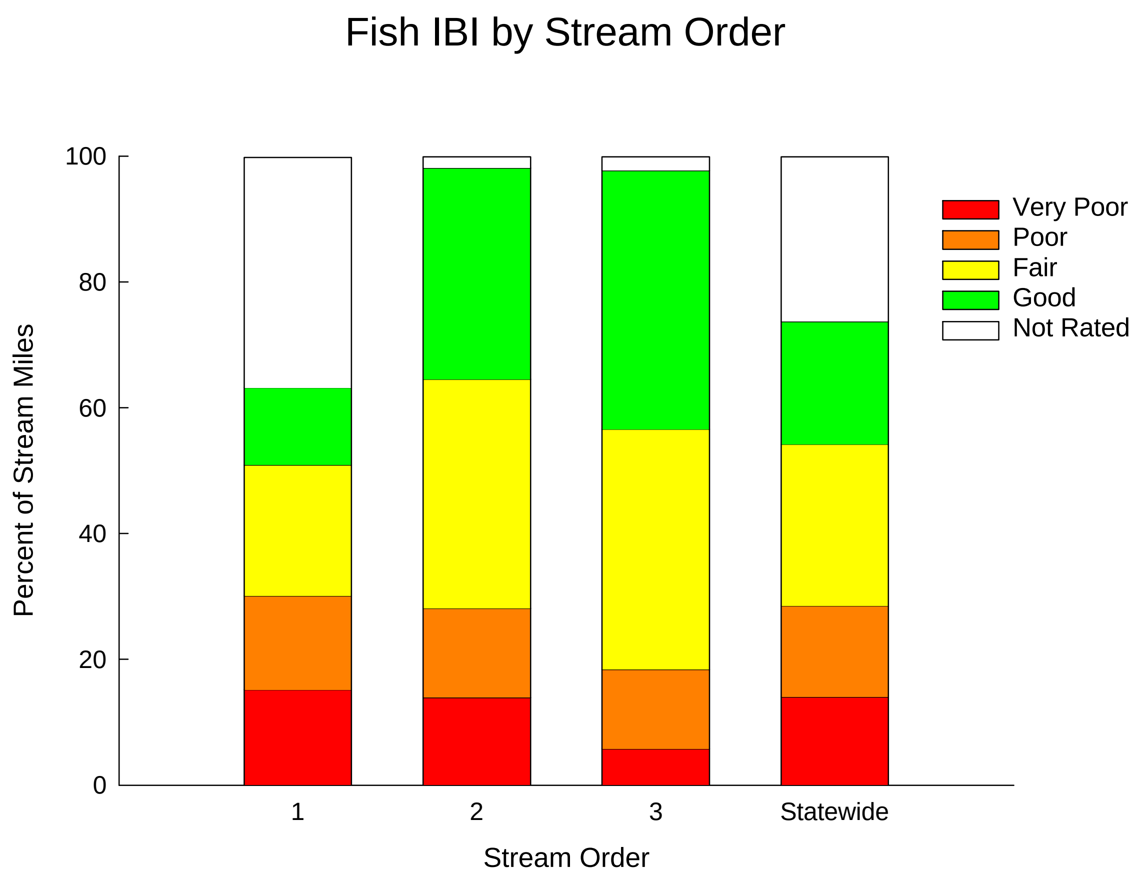

Figure 5-5. Fish Index of Biotic Integrity (IBI) scores by stream order, for basins sampled in the 1995-97 MBSS, as the percentage of stream miles in each category: 4.0 - 5.0 good, 3.0 - 3.9 fair, 2.0 - 2.9 poor, and 1.0 - 1.9 very poor. No IBI score was assigned to sites with watershed area < 300 acres.

Table 5-6. Estimated percentage of stream miles in each fish IBI category for basins sampled in the 1995-1997 MBSS

	Good	Std. Error	Fair	Std. Error	Poor	Std. Error	Very Poor	Std. Error	% Rated
Basin									
Youghiogheny 1995	26.7	10.6	23.9	9.3	17.2	8.9	12.4	6.9	80.1
Youghiogheny 1997	20.4	8.3	23.6	4.9	2.4	1.8	20.1	9.3	66.5
North Branch Potomac	18.9	6.5	8.8	2.8	11.7	5.8	29.1	8.3	68.6
Upper Potomac	8.0	3.8	18.4	5.3	9.4	2.6	22.9	6.8	58.7
Middle Potomac	18.5	3.8	21.6	4.4	14.7	4.8	18.9	5.4	71.7
Potomac Washington Metro	15.5	4.9	27.0	6.8	12.4	4.8	16.9	6.1	73.7
Lower Potomac	33.3	8.0	19.6	7.6	10.5	5.7	12.9	6.6	76.4
Patuxent	14.3	3.6	23.4	5.7	31.0	6.7	9.0	4.3	77.6
West Chesapeake	9.3	7.9	7.6	2.8	8.4	3.3	12.4	8.2	37.7
Patapsco 1995	32.3	7.6	27.7	7.1	14.5	5.3	8.6	4.9	83.1
Patapsco 1996	10.7	4.0	37.7	7.9	6.0	3.5	25.6	7.4	80.1
Gunpowder	21.1	7.1	24.9	6.3	14.1	6.7	0.0	0.0	60.1
Bush	33.4	12.1	20.4	11.8	25.0	14.6	0.0	0.0	78.8
Susquehanna	26.6	7.0	22.7	9.9	15.1	8.4	11.9	8.1	76.3
Elk	37.8	14.8	30.7	14.8	21.0	14.3	0.0	0.0	89.5
Chester	21.7	8.6	35.2	11.2	20.5	9.7	5.6	5.6	83.1
Choptank 1996	33.4	15.1	55.9	18.7	0.0	0.0	0.0	0.0	89.3
Choptank 1997	14.7	5.1	31.1	16.5	23.2	14.3	10.4	10.3	79.3
Nanticoke/Wicomico	3.9	2.2	69.6	19.1	18.1	11.6	0.0	0.0	91.6
Pocomoke	12.5	9.8	48.1	17.4	9.7	9.7	0.0	0.0	70.4
Stream Order									
1	12.3	7.7	20.8	7.1	14.9	6.2	15.2	8.0	63.2
2	33.6	7.9	36.4	8.6	14.2	5.9	13.9	8.4	98.1
3	41.1	12.1	38.2	10.2	12.6	6.4	5.8	4.8	97.8
Statewide	19.5	7.1	25.7	5.5	14.5	5.0	14.0	7.0	73.8

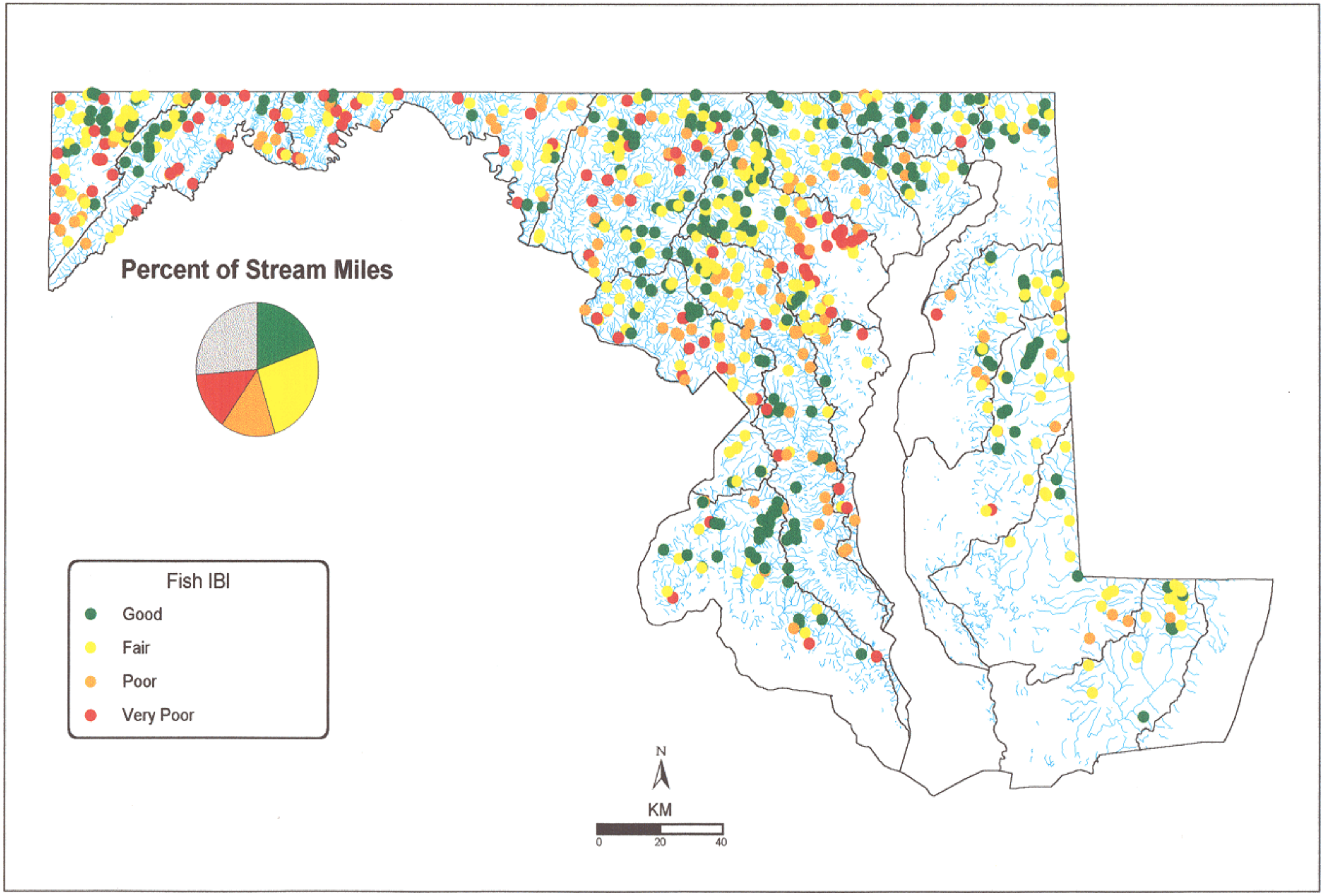

Figure 5-6. Geographic distribution of fish Index of Biotic Integrity (IBI) scores throughout the study area, including the statewide distribution of the percentage of stream miles with fish in each category: 4.0 - 5.0 good, 3.0 - 3.9 fair, 2.0 - 2.9 poor, and 1.0 - 1.9 very poor. No IBI score was assigned to sites with watershed area < 300 acres.

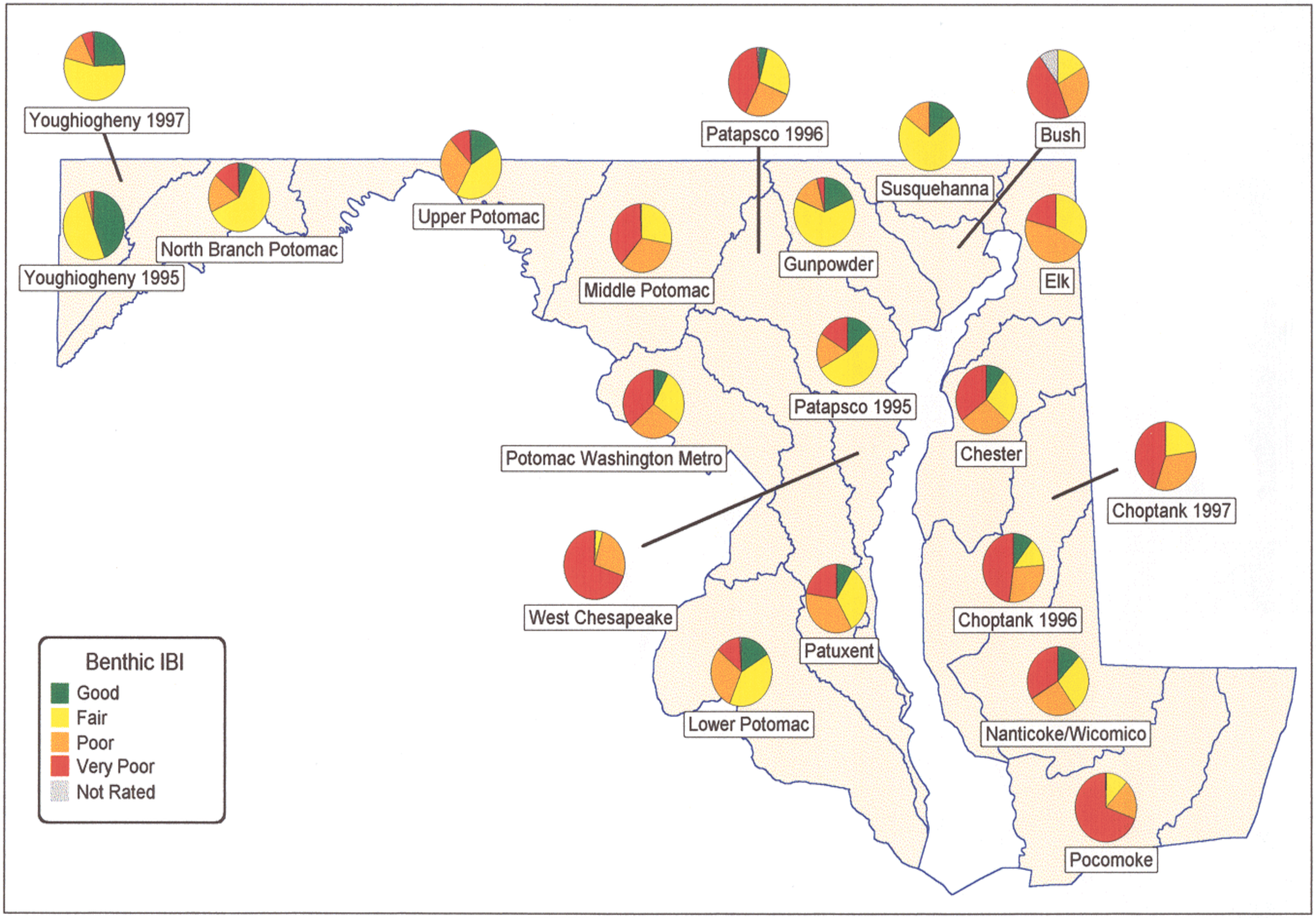

Figure 5-7. Geographic distribution of benthic Index of Biotic Integrity scores for basins sampled in the 1995-97 MBSS, as the percentage of stream miles in each category: 4.0 - 5.0 good, 3.0 - 3.9 fair, 2.0 - 2.9 poor, and 1.0 - 1.9 very poor

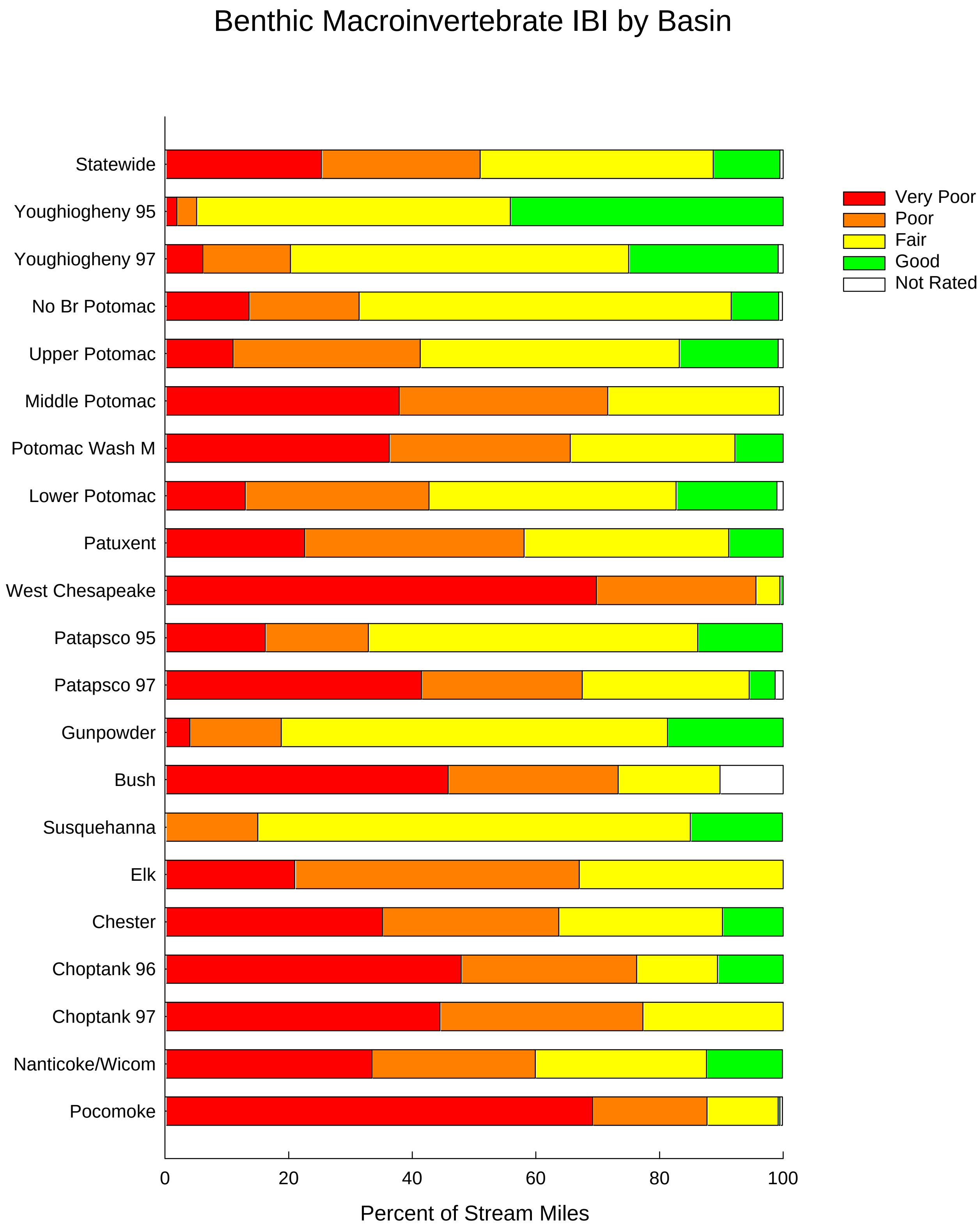

Figure 5-8. Benthic Index of Biotic Integrity (IBI) scores for basins sampled in the 1995-1997 MBSS, as the percentage of stream miles in each category: IBI 4.0 - 5.0 good, 3.0 - 3.9 fair, 2.0 - 2.9 poor, and 1.0 - 1.9 very poor

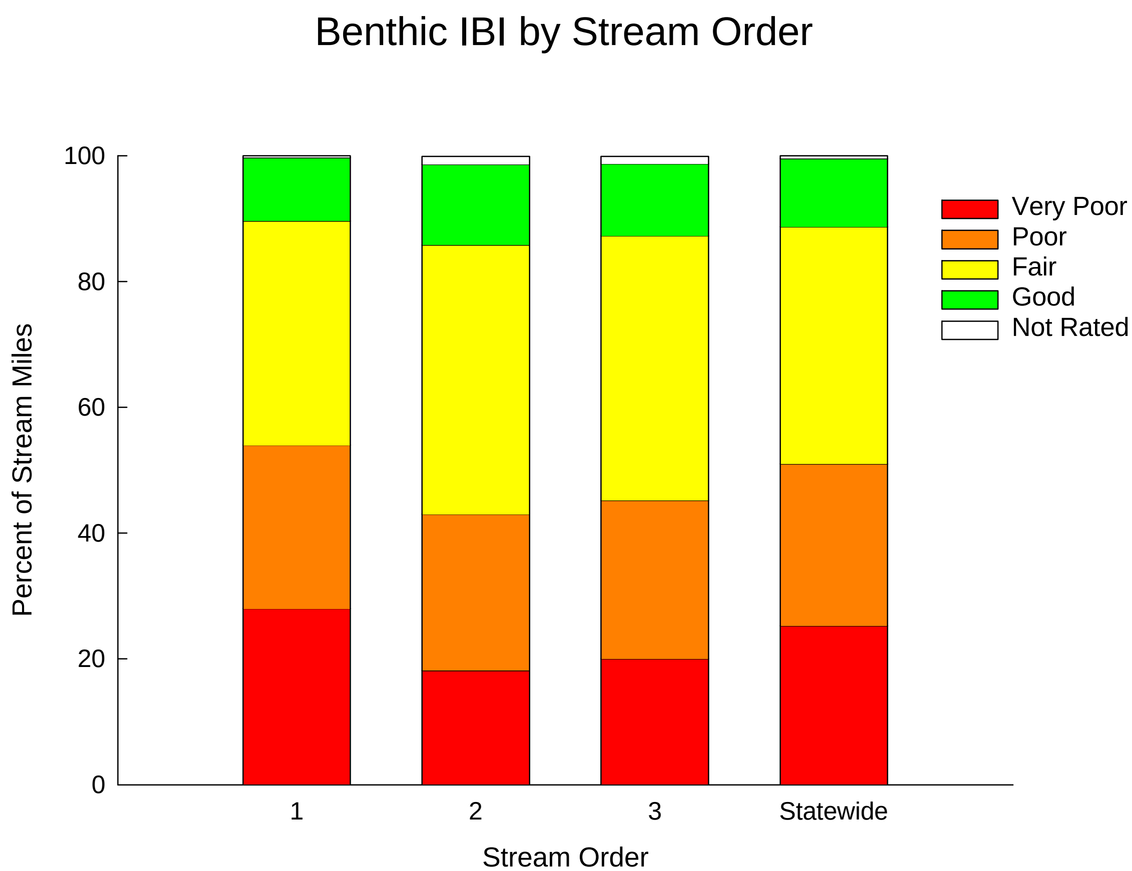

Figure 5-9. Benthic Index of Biotic Integrity (IBI) scores by stream order, for basins sampled in the 1995-97 MBSS, as the percentage of stream miles in each category: IBI 4.0 - 5.0 good, 3.0 - 3.9 fair, 2.0 - 2.9 poor, and 1.0 - 1.9 very poor

Table 5-7. Estimated percentage of stream miles in each benthic IBI category for basins sampled in the 1995-1997 MBSS

	Good	Std. Error	Fair	Std. Error	Poor	Std. Error	Very Poor	Std. Error	% Rated
Basin									
Youghiogheny 1995	44.1	11.1	50.8	11.3	3.2	1.7	1.9	1.0	100.0
Youghiogheny 1997	24.2	9.0	54.7	11.3	14.2	7.5	6.1	5.3	99.2
North Branch Potomac	7.7	3.9	60.2	9.1	17.8	6.3	13.6	5.4	99.4
Upper Potomac	16.0	5.3	41.9	7.7	30.3	7.3	11.0	5.1	99.2
Middle Potomac	0.0	0.0	27.8	6.0	33.7	5.7	37.9	6.7	99.3
Potomac Washington Metro	7.8	4.3	26.6	6.7	29.3	7.4	36.3	7.9	100.0
Lower Potomac	16.3	5.6	40.0	9.3	29.7	8.8	13.0	6.3	99.0
Patuxent	8.8	3.4	33.1	6.4	35.5	6.9	22.6	6.0	100.0
West Chesapeake	0.5	0.5	3.9	1.8	25.8	10.2	69.8	16.8	100.0
Patapsco 1995	13.7	5.9	53.3	9.2	16.7	6.1	16.2	5.5	100.0
Patapsco 1996	4.2	3.3	27.0	7.4	26.0	7.0	41.5	8.2	98.7
Gunpowder	18.7	7.6	62.5	9.8	14.8	6.8	4.0	4.0	100.0
Bush	0.0	0.0	16.5	10.6	27.5	11.8	45.8	16.3	89.8
Susquehanna	14.9	7.9	70.0	11.7	15.0	7.8	0.0	0.0	100.0
Elk	0.0	0.0	33.0	14.8	46.0	17.3	21.0	14.3	100.0
Chester	9.9	5.6	26.5	9.0	28.5	10.5	35.2	11.3	100.0
Choptank 1996	10.6	8.5	13.1	8.5	28.4	12.9	47.9	14.8	100.0
Choptank 1997	0.0	0.0	22.7	10.6	32.8	13.2	44.5	14.2	100.0
Nanticoke/Wicomico	12.3	8.6	27.7	13.8	26.4	13.8	33.5	15.4	100.0
Pocomoke	0.3	0.3	11.5	7.4	18.5	10.1	69.2	14.5	99.7
Stream Order									
1	10.1	6.5	35.6	9.4	26.0	6.8	28.0	11.2	99.7
2	12.8	3.8	42.8	14.7	24.9	6.5	18.1	9.9	98.6
3	11.4	6.2	42.1	9.4	25.2	8.4	20.0	6.9	98.7
Statewide	10.8	5.0	37.7	10.0	25.7	5.5	25.3	9.7	99.4

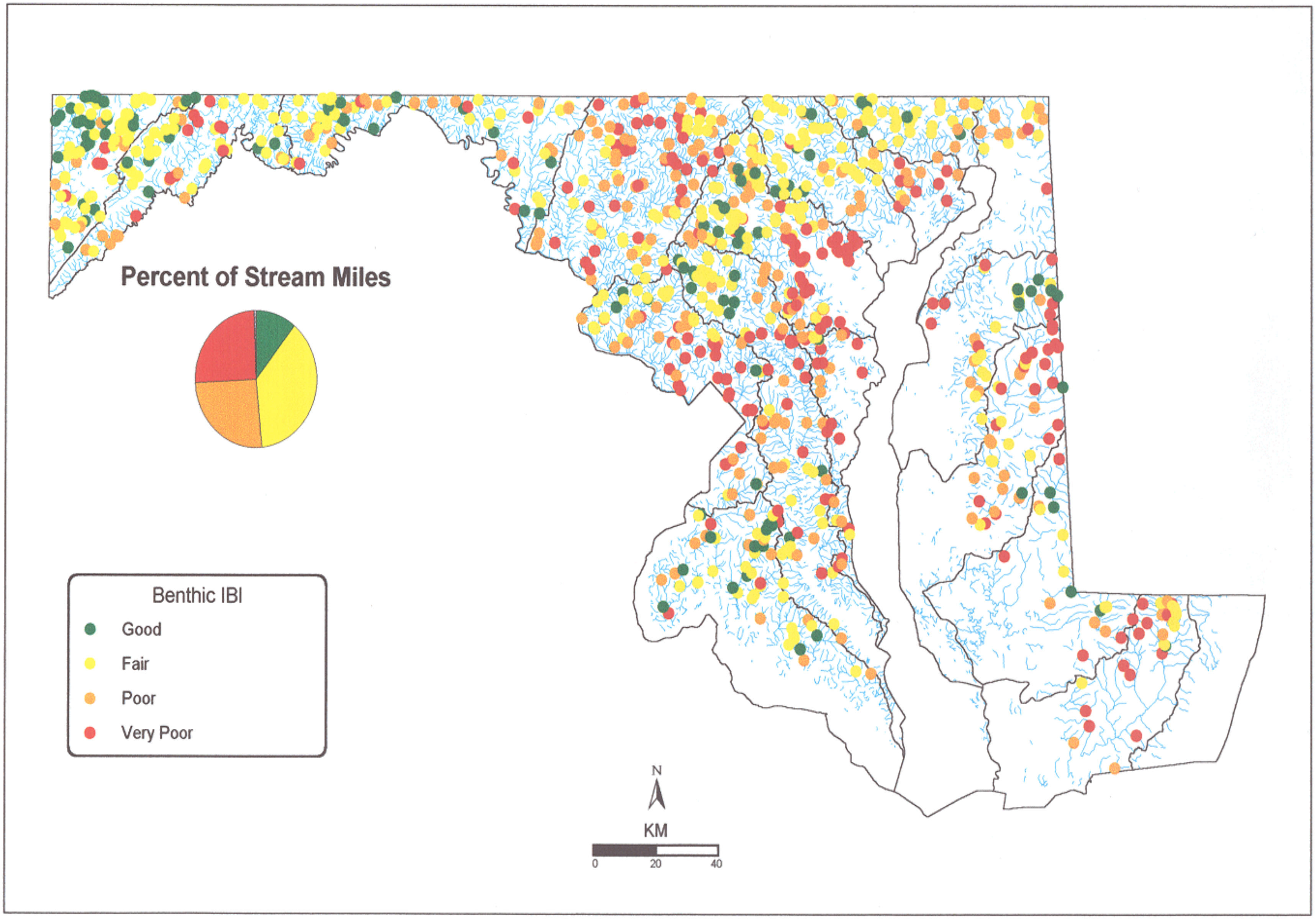

Figure 5-10. Geographic distribution of benthic Index of Biotic Integrity (IBI) scores throughout the study area, including the statewide distribution of the percentage of stream miles with benthic IBI scores in each category

First-order streams sampled throughout the state had a smaller percentage of stream miles in the good and fair categories, and a greater percentage rated very poor, than did larger streams. Again, this may be indicative of more highly impacted conditions in first-order streams.

5.3.3 The Hilsenhoff Biotic Index

The Hilsenhoff Biotic Index (Hilsenhoff 1977, 1987, 1988; Klemm et al. 1990; Plafkin et al. 1989) was also used as an indicator of the biological condition of streams surveyed. The Index evaluates pollution tolerance, primarily tolerance to organic pollution. Hilsenhoff Biotic Index scores tend to increase with degradation. A tolerance value of 0 to 10 is assigned to each taxon collected; the index is calculated as an average tolerance value for the assemblage, weighted by the abundance of each taxon. Currently, tolerance values for Maryland benthic taxa are derived primarily from research in the Midwest (Hilsenhoff 1987), New York (Bode 1988), and North Carolina (Lenat 1993).

Although the Hilsenhoff Biotic Index is most useful for discerning degradation due to organic pollution, and has not been calibrated specifically for Maryland, it provides an additional means of applying threshold values to determine degradation. The original Hilsenhoff scale contained threshold values for six categories of degradation. Bode and Novak (1995) modified this scale to include four categories ranging from non-impacted to severely impacted. For the purposes of this Survey, these four categories were adopted with narrative ratings assigned as follows:

- Scores of 0 to 4.5 are rated good
- Scores of 4.51 to 6.5 are rated fair
- Scores of 6.51 to 8.5 are rated poor
- Scores of 8.51 to 10.0 are rated very poor

Hilsenhoff scores at MBSS sites ranged from 0.41 to 9.97.

Statewide, the greatest percentage of stream miles were in fair condition (42%). An estimated 36% were in good condition, 16% were in poor condition, and 3% were very poor based on the Hilsenhoff Biotic Index. Three percent of stream miles were not rated. Sites were not used in the calculation of the Hilsenhoff Biotic Index if they contained too few individuals for the Index to be meaningful. Seven basins contained stream miles that rated in very poor condition: the North Branch Potomac, Middle Potomac, Patuxent, Patapsco (1996 sampling), Bush, and Choptank (1997 sampling), and the Potomac Washington Metro basin with the highest percentage of stream miles rated as very poor (12%). With the exception of the Pocomoke and the Choptank (1997 sampling) basins, each basin had some stream miles rated as good, with the highest percentage in the 1997 sampling of the Gunpowder basin (88%). Figures 5-11 and 5-12 show the breakdown of Hilsenhoff Biotic Index scores by basin and by stream order.

5.4 COMPARISON OF FISH AND BENTHIC ASSESSMENTS

For the 17 basins sampled during the 1995-1997 MBSS, there was a significant linear relationship between fish IBI scores and benthic IBI scores, although there was a large amount of variation when data from all basins were pooled (linear regression, $p < 0.001$, $r^2=0.12$). When basins were examined individually, there was a significant linear relationship between fish IBI and benthic IBI in nine of the basins sampled ($r^2=0.11$ to 0.42). For example, the Patapsco basin showed a relationship between the fish and benthic IBI (Figure 5-13; $r^2=0.34$). In this basin, sites that had low fish IBI scores also had low benthic IBI scores. There are several likely reasons for the differences between the fish IBI and the benthic IBI results. The first is that the different IBI scores may reflect different responses to stressors (i.e., pollution or physical habitat degradation) by the two groups of organisms. For example, fish are more mobile than benthic organisms and may be better able to temporarily avoid a stress upon stream water quality. Fish can live in a wide variety of habitats, so some of the low benthic IBI scores may reflect natural conditions where prime benthic habitat (e.g., well-aerated riffles) does not exist. In other situations, benthos may be more directly affected by habitat degradation that causes sedimentation or even movement of unstable substrates. Finally, due to small watershed size, 98 sites were not rated for the fish IBI. All of these sites were assigned benthic IBI scores (the majority of which were rated poor or very poor), resulting in differences in the percentages of stream miles in each IBI category. In a comparison of results at all sites statewide, fish and benthic IBI scores for the same site were most often within 1.0 IBI unit of one another. The fish IBI tended to be slightly higher than the benthic IBI, particularly in second- and third-order streams. Regional differences did not appear to explain differences, as these results were consistent across all regions (Coastal Plain, Piedmont, and Highland).

For the 17 basins there was also a significant linear relationship between fish IBI scores and the Hilsenhoff Biotic Index, although there was a large amount of variation when data from all sampled basins were pooled

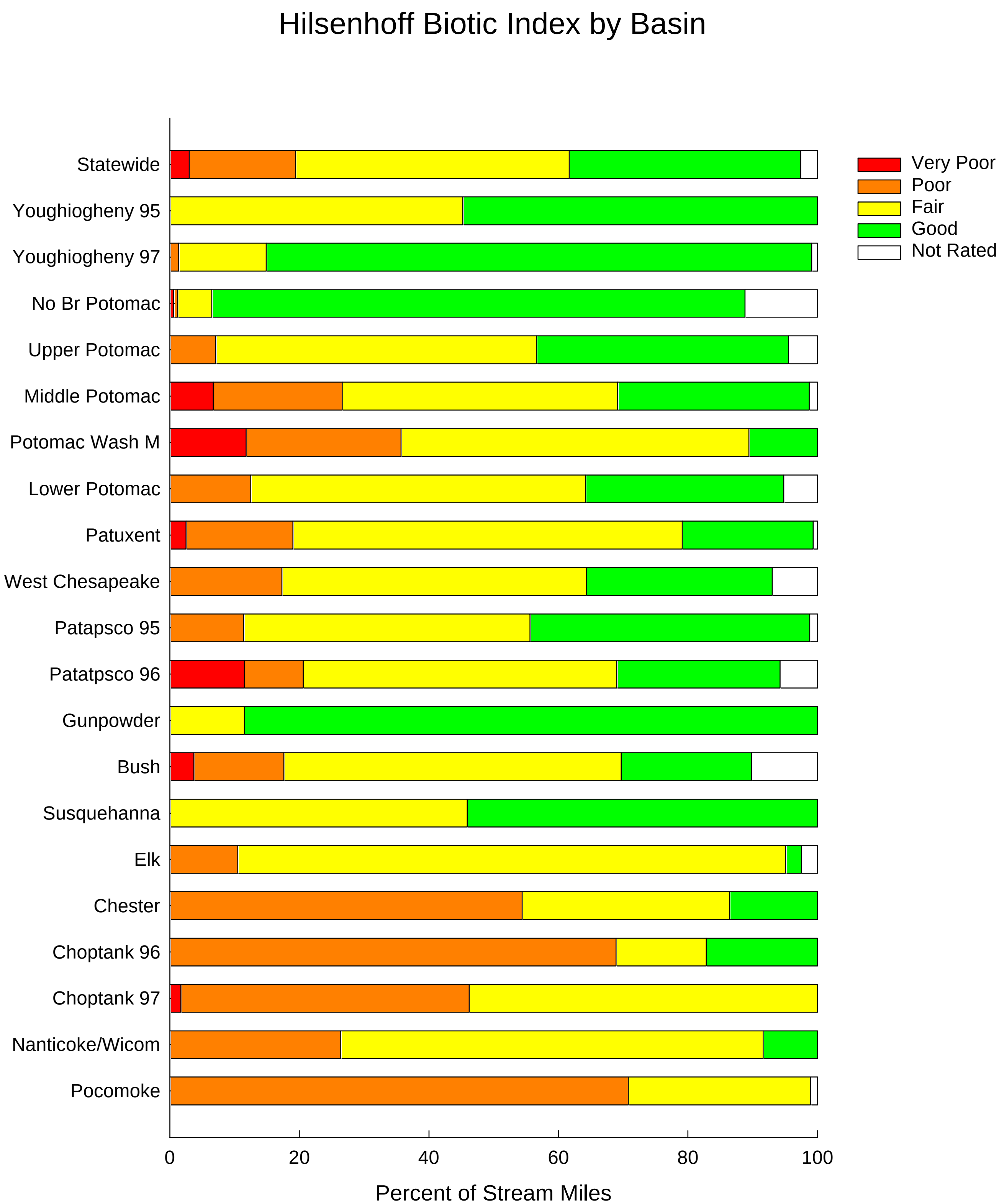

Figure 5-11. Hilsenhoff Biotic Index scores for basins sampled in the 1995-97 MBSS, as the percentage of stream miles in each category: 0 - 4.5 good, 4.51 - 6.5 fair, 6.51 - 8.5 poor, and 8.51 - 10.0 very poor

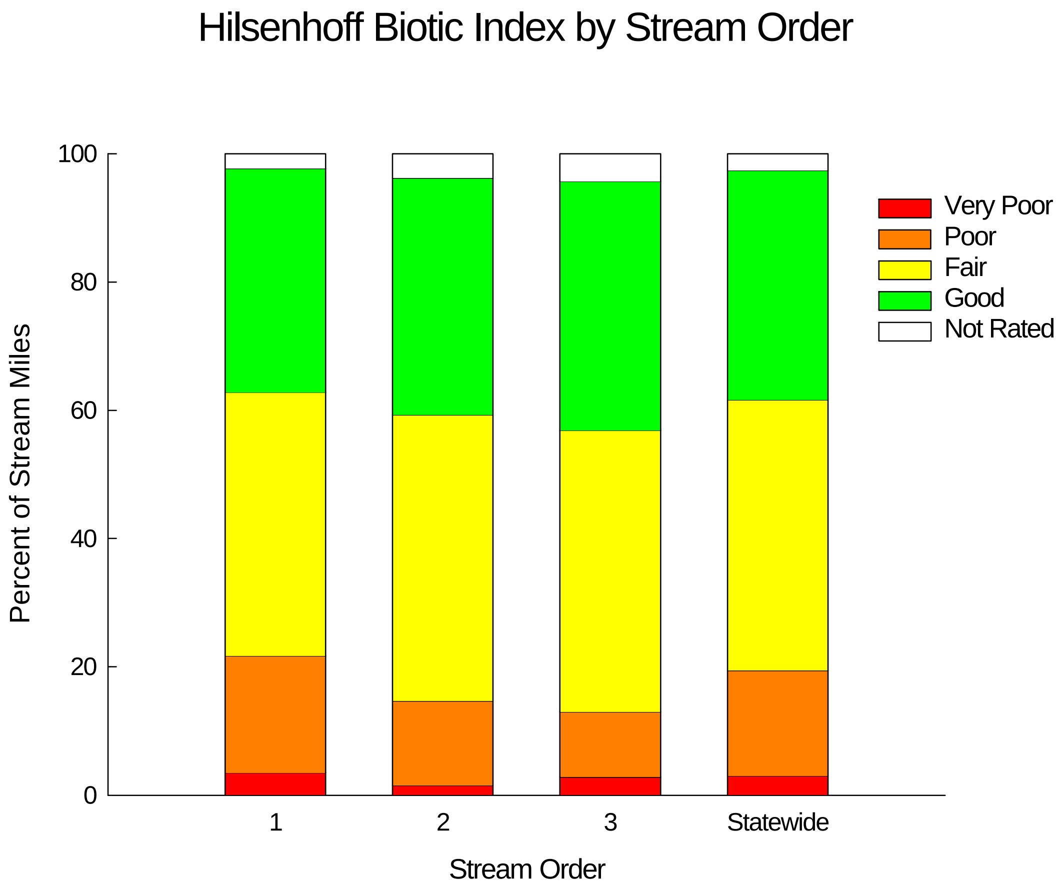

Figure 5-12. Hilsenhoff Biotic Index scores by stream order, for basins sampled in the 1995-97 MBSS, as the percentage of stream miles in each category: 0 - 4.5 good, 4.51 - 6.5 fair, 6.51 - 8.5 poor, 8.51 - 10.0 very poor

(linear regression, $p<0.001$, $r^2=0.021$). As expected, this relationship was a negative one, given that IBI scores decrease with increased degradation while Hilsenhoff scores increase. When basins were examined individually, there was a significant linear relationship between fish IBI and Hilsenhoff Biotic Index in eight of the basins sampled ($r^2=0.05$ to 0.49).

It was expected that there would be a relationship between the benthic IBI and the Hilsenhoff Biotic Index, as both measure the quality of the benthic invertebrate community in a stream. A significant linear relationship does indeed exist between the two indicators for all basins sampled (linear regression, $p < 0.001$, $r^2=0.35$). Again, the relationship was a negative one given that IBI scores decrease with degradation while Hilsenhoff scores increase. When basins were examined individually, there was a significant linear relationship between benthic IBI and Hilsenhoff Biotic Index in 13 of the basins sampled ($r^2=0.13$ to 0.74). For example, there was a relatively strong relationship in the Patuxent basin (Figure 5-14; $r^2=0.42$). In general, sites in this basin that had low benthic IBI scores also had high Hilsenhoff Biotic Index scores.

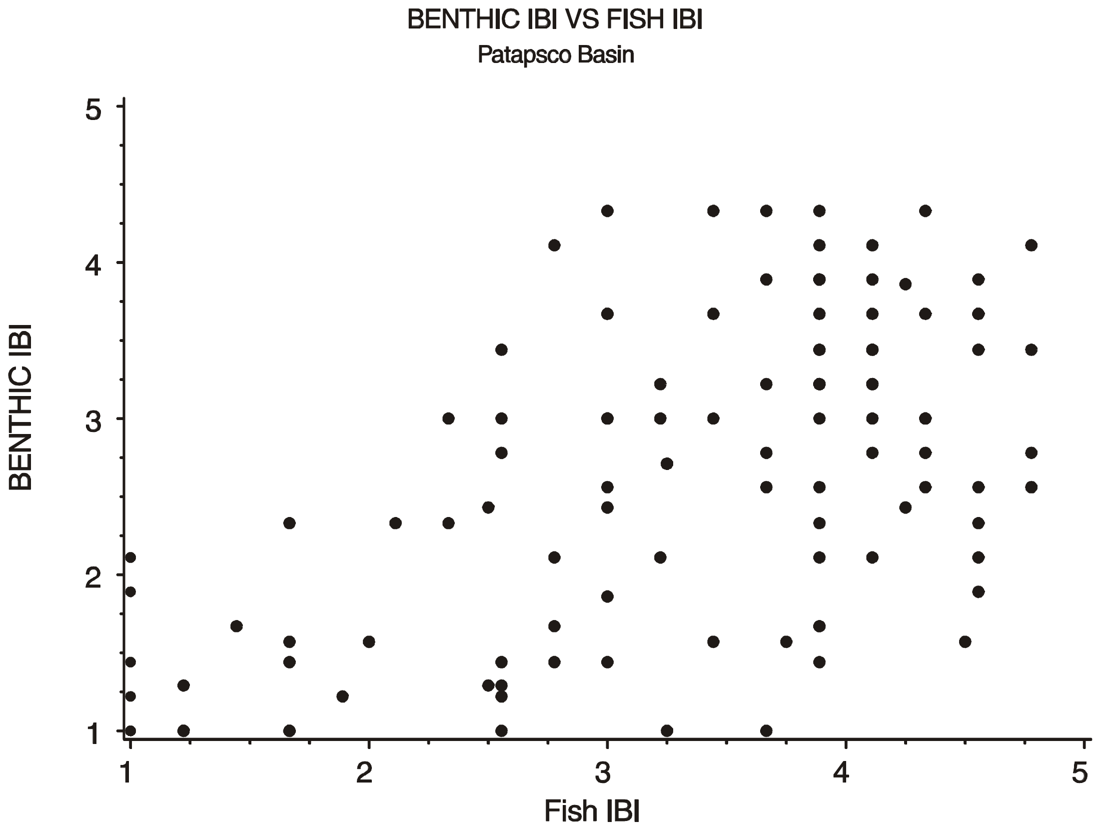

Figure 5-13. Relationship between fish IBI and benthic IBI for the Patapsco basin (linear regression, $p < 0.001$, $r^2=0.34$)

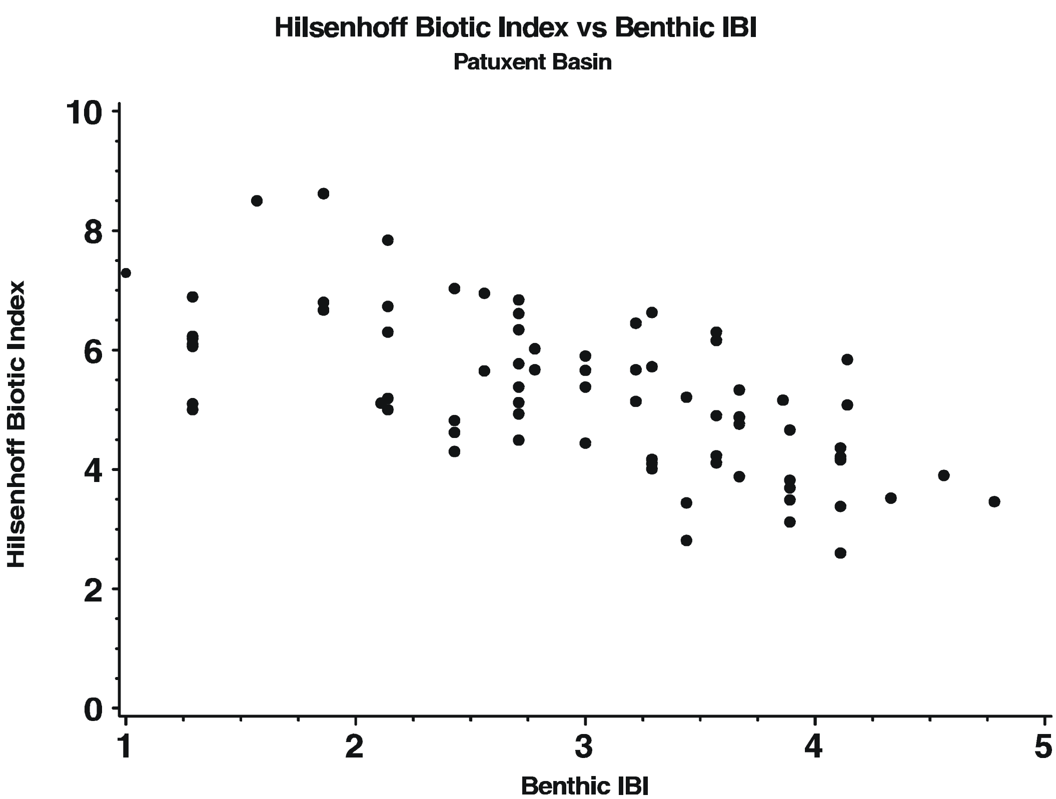

Figure 5-14. Relationship between benthic IBI and Hilsenhoff Biotic Index for the Patuxent basin (linear regression, $p < 0.001$, $r^2=0.42$)